

Serial No. 09/909,993
Reply to Office Action dated September 10, 2003

Docket No. FSU-003

Amendments to the Drawings:

The attached drawings includes changes to Figs.10-12. These sheets, which include Figs. 10-12, replace the original sheet including Figs.10-12. The changes to Figs. 10-12 correct inconsistencies with the specification. No new matter is added.

Attachment: Replacement Sheet
Annotated Sheet Showing Changes

Amendments to the Specification:

Please replace paragraph [47] with the following amended paragraph:

[47] It should be noted that a comparison of LAPR thresholds is not always straightforward. The definition of what constitutes the threshold depends on whether energy fluence or intensity is used, how the spot size and energy density or intensity are defined and how the cleaned area is defined. For example, while the maximum energy density threshold for CO₂ is significantly higher (approximately 2.2J/cm²) than for an excimer laser (approximately 100-300 mJ/cm²), the pulse length is also longer (about ~~approximately~~ 200 ns for a CO₂ laser as compared to an excimer laser at about 20 ns). The intensity thresholds are, therefore, comparable. When the upper limit to the energy density is determined by substrate damage, the intensity is frequently the most appropriate measurement as short pulses damage more readily than long pulses in most substrate systems.

Please replace paragraph [69] with the following amended paragraph:

[69] An additional problem that must be solved before a successful industrial system is implemented is the prevention of redeposition of removed particles. The most fundamental requirement for redeposition prevention is that the velocity of the particle be greater than the escape velocity. As soon as the particle has been removed from the surface, it is subject to drag forces from the surrounding atmosphere and these retarding forces are more significant for smaller particles. Two solutions have been proposed and implemented to some degree – reduce the pressure of the surrounding ambient to increase the mean free path of the removed particle,

or use a gas jet parallel to the surface to entrain the removed particle. It has also been suggested that the particles could be ionized and trapped electrostatically. Co-pending application Serial No. 09/909,992 [Attorney Docket No. FSU-0004] which is hereby incorporated by reference, discloses using thermophoresis to prevent redeposition of particles. ~~Alternatively,~~ a cold plate in a vacuum or low pressure ambient could be provided to draw removed particles (and any ETM) away from the surface and prevent them from redepositing. In any event, redeposition is another issue that ~~much~~ must be addressed when utilizing LAPR.

Please replace paragraph [87] with the following amended paragraph:

[87] Certain refinements can be included in the foregoing model, although as will be appreciated the model is adequate for most purposes. With respect to one refinement, for small particles of interest, the laser energy is efficiently diffracted around the particle, allowing absorption of the bulk of energy by the energy transfer medium in the interstices. For larger particles, however, some of the medium in the interstices ~~water~~ can be shadowed by the particle, with the result being a decrease in coupling efficiency of the laser to the medium. The optical properties of the particle and substrate can also affect the energy absorption.

Please replace paragraph [90] with the following amended paragraph:

[90] Water provides a good energy transfer medium in that it is capable of significant superheating, thereby storing significant energy per volume. This stored energy is converted to kinetic energy on explosive evaporation and translated to the surface particle. Water is highly transparent at all of the visible and UV wavelengths longer than approximately 157 nm. In some

cases, water or water/alcohol mixtures may be used with nonabsorbing pulsed lasers, such as excimer lasers, on silicon or metal substrates using substrate absorption. The laser heated substrate transfers energy to the energy transfer medium via thermal conduction and effects explosive evaporation and particle removal.

Please replace paragraph [92] with the following amended paragraph:

[92] According to the methods and apparatus of the invention, the wavelength of the laser energy, the ~~pulse~~ length and shape of the laser ~~energy pulse~~, the laser energy density, the laser beam size and/or shape, the laser irradiation geometry, the ambient conditions, the amount and disposition of the energy transfer medium and/or the composition of the energy transfer medium are precisely and selectively controlled. The exact parameters may be calculated for the specific application and environment, including consideration of the optical constraints of the materials and the size of the particles. The wavelength of the laser should be chosen to target either the particle, substrate, the ETM ~~[[of]]~~ or some combination thereof. The energy density should be above the removal threshold but below the damage threshold. Further, the energy density should be sufficient to be absorbed by the particle, the substrate, or the energy transfer medium, either directly or by conduction from the sample or substrate, or some combination thereof. The pulse length of the laser is preferably sufficiently short in order to achieve the desired temperature distribution of the energy transfer medium, but not any shorter in order to decrease the likelihood of substrate damage. The laser beam shape and/or size is preferably as large as possible to clean as large an area as possible. Ideally, the laser beam is a uniformly

intense beam. The irradiation geometry is chosen to optimize the energy transfer to the ETM and minimize substrate or device damage. The energy transfer medium is preferably capable of providing sufficient kinetic energy to the particle in order to remove the particle during the explosive evaporation of the energy transfer medium. The energy transfer medium may be introduced as a uniform layer of a particular thickness onto the substrate, may be introduced so as to be condensed only in the capillary spaces under the particle, or any combination thereof, the exact selection being dependent on the substrate/particle system being used. Additionally, the composition of the energy transfer medium may be selected such that it will couple more efficiently to the laser being used.